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Urban density and child health and wellbeing: A scoping review of the literature

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ABSTRACT

This scoping review explores the relationship between urban density and child health and wellbeing, focusing on how urban density has been measured and its association with various child health outcomes. By analysing 53 studies spanning from 1972 to 2023, we identify significant variability in how urban density is defined and measured and mixed evidence regarding its relationship with different child health outcomes. We also highlight context-specific findings, which may be connected to a range of dynamic and interconnected local and socio-cultural factors. While most studies showed mixed or inconclusive results for physical health and mental health and wellbeing, some consistent findings were observed for positive associations between urban density and growth and nutritional status in studies from Asia and Africa, and for negative impacts on child development in studies from Europe and North America. The review highlights the need for improved reporting standards, consistent terminology, and context-specific approaches to better understand and address the complex interplay between urban density and child health. It underscores the importance of considering broader social determinants and the unique experiences of children within urban environments for improved policy, practice and placemaking, advocating for participatory research methods to capture children's perspectives on urban density.

1. Introduction

Children's environments profoundly influence their health and wellbeing. Positive impacts arise from sanitation, service access, and urban design that promotes physical activity and healthy nutrition behaviours. Conversely, negative impacts include increased exposure to pollution and risk of traffic-related injury (Cummins and Jackson, 2001; Martin et al., 2023). Urbanisation represents a major demographic shift with significant implications for human health (Galea and Vlahov, 2005). For children, this shift is particularly impactful as urban environments are often designed without considering their specific needs (Carroll et al., 2019; Davis and Jones, 1996). Relationships between child health and specific factors associated with more urbanised environments have been studied individually (e.g., walkability, streetscape design, greenspace etc.) (Pitt et al., 2021), and interventions focusing on improving aspects of urban environments have shown promise for improving child health (Audrey and Batista-Ferrer, 2015). The measurement and understanding of urbanization display significant variability, influencing how health outcomes are both assessed and addressed. Liao and Furuya (2023) underscore the importance of economic development in the advancement and research focus on children in cities, pointing to differing priorities and methodologies in urban studies. This variation highlights the need for a global lens that accommodates diverse approaches to urbanization, ensuring that the measurement tools and conceptual frameworks are sensitive to the nuances of different urban contexts.

Glaeser and Henderson (2017) argue that the definition of urbanization itself can significantly influence research outcomes and policy

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implications. They suggest that urbanization should be viewed not just as a demographic transition but also through the lens of economic opportunities and environmental challenges that accompany urban growth. This perspective is crucial for understanding the broad spectrum of urban health outcomes, ranging from communicable diseases in densely populated less affluent areas to non-communicable diseases in more affluent urban areas (Black et al., 2024; Goenka and Andersen, 2016). Moreover, the United Nations Human Settlements Programme emphasizes the role of governance and policy in shaping urban environments and, consequently, health outcomes (United Nations Human Settlements Programme (UN-Habitat), 2016). Their report outlines the divergent paths of urbanization in different regions, with Sub-Saharan Africa and Asia experiencing rapid urban growth without adequate planning, leading to increased health risks. In contrast, European and North American cities, with more structured urban development, face different health challenges, such as obesity and poor mental health. Sevilla et al. (2018) provide a global comparison of urban health outcomes, revealing that the impacts of urbanization on health are mediated by factors such as infrastructure, public health services, and social determinants of health. Their study illustrates how cities like Tokyo and Singapore, which have invested heavily in public transportation and healthcare infrastructure, exhibit lower rates of disease or health conditions related to urbanization compared to cities that lack such investments. In this sense, there is a call for more nuanced urban health metrics that capture intra-urban diversity, disparity, and variation in the social determinants of health (Montgomery et al., 2013; Patel and Burke, 2009).

The interplay between urban health determinants and health outcomes is a critical area of concern. Hathi et al. (2017) illustrate how the combination of population density and sanitation practices significantly impacts child health. This theme emphasizes the importance of considering a range of health determinants—including environmental, socio-economic, and infrastructural factors—when assessing health outcomes in urban settings. The UN-Habitat *My Neighbourhood* project objectives (compact, connected, vibrant, inclusive, resilient) and their associated principles encourage consideration of the complexities of density and community wellbeing and how to achieve density in a balanced way (Ignatova, 2024). Such a comprehensive approach is vital for designing effective interventions and policies. A recurring theme in urban health research is socio-economic disparity and resulting health inequity within urban environments. Fotso (2006) sheds light on the stark inequities in child malnutrition across and within urban and rural areas, with particular attention to the disparity of the urban poor. This theme stresses the necessity of policies and interventions that specifically target the underlying causes of health inequity, aiming to reduce the gaps between diverse socio-economic groups.

The global differences in terminology, concepts, and contexts of urbanicity, affecting the understanding and application of urban health research must also be considered. Harpham (2009) calls for a multi-level and multi-sectoral approach to urban health, highlighting the diverse determinants and outcomes of health in urban contexts across countries. This perspective underscores the importance of transitioning from a focus on vulnerability to fostering resilience, encouraging researchers and policymakers to embrace a global outlook that acknowledges and addresses the distinct challenges of urban health worldwide. As an example, the conceptualisation of "urban" varies dramatically across regions, influencing how urban health issues are identified, measured, and addressed. For instance, The World Bank (2015) discusses how the criteria for what constitutes an urban area differ from one country to another, often based on population size, density, and economic functions. These variations can lead to discrepancies in assessing urban health needs and prioritizing interventions. Rapid urbanization can outpace the development of essential infrastructure and services, leading to unique health challenges, such as increased exposure to infectious diseases, pollution, and non-communicable diseases (McMichael, 2000). Inequities in health and social outcomes are compounded not only by insufficient development of resources (i.e., *hyper*urbanisation combined with *under*development), but also inequitable distribution of resource development (Fix and Arantes, 2022). Additionally, Khan et al. (2022) highlights how language used to dichotomise countries has created a false hierarchy among nations, and ignores the independent identities and strengths of nations. These complexities necessitate urban health research and policies that are grounded in the specific socio-economic and environmental contexts of each area. Intentional approaches that capture and describe such nuance and inequities are needed; use of frameworks such as the Towards Healthy uRbanism: InclusiVe Equitable Sustainable (THRIVES) framework (Pineo, 2022) and the UN Habitat My Neighbourhood principles (Ignatova, 2024) is an important step forward in this field. Ultimately, urban health is not solely the purview of healthcare providers but is also influenced by broader societal factors. By adopting a global perspective that appreciates the diverse contexts and challenges of urban environments, researchers and policymakers can contribute to the development of resilient urban communities that are better equipped to achieve positive health outcomes for children. It is worth noting that urbanization and urban density are both distinct and interrelated; urbanisation can be considered as the *process* of increasing density (usually population) of an area and is generally associated with the distinction between urban and rural areas, while urban density is the *result* of urbanisation, again usually a measure of the population within a given area. Research interested in urbanisation, distinguishing urban from rural areas, and urban density all have similar underpinning concepts around the characteristics that more urbanised and more densely populated areas may have in relation to health, for example access to services and public infrastructure. Given the inconsistencies in the use of these terms in the literature, we focus on both urbanisation and urban density, as a first step in understanding how residing in more dense/urbanised areas is conceptualised and linked with an array of child health outcomes.

Numerous studies have examined links between urbanisation/density and health outcomes. However, to the authors' knowledge no structured review of this literature currently exists to provide a global understanding of how urban density has been measured, and how this is related to an array of child health outcomes. This information is necessary to contextualise individual study findings in the broader evidence base, aid critique in the field around defining and measuring density, inform future study design for comparability with the international evidence base, and to generate conversations about improving reporting and measurement in the field overall. Accordingly, this review provides important new evidence by exploring the following two research questions: 1) how has urban density been measured in studies of child health? and 2) in this body of research, how is urban density associated with child health?

In this article, we uncover patterns in how urban density has been measured and how it relates to child health across four categories: child growth and nutritional status, physical health, mental health and wellbeing, and child development (encompassing children's behavioural, emotional, and social development). Drawing from Khan et al. (2022), we are compelled to avoid the use of categorisation of countries by income or 'development' and instead report findings for countries and their regions.

2. Methods

2.1. Protocol

In this scoping literature review the PRISMA-ScR protocol (Tricco et al., 2018) was followed. Due to our broader interdisciplinary focus and aim to address urbanization from multiple perspectives, a scoping review was preferred to a systematic review - which are typically narrower in their scope (Munn et al., 2018). Scoping reviews are useful when research questions are of an exploratory nature and the evidence base is anticipated to be broad, heterogeneous, and not well suited to meta analyses (Arksey and O'Malley, 2005; Grant and Booth, 2009; Munn et al., 2018; Paré et al., 2015). Unlike systematic reviews, which aim to comprehensively interrogate all available literature on a specific topic, scoping reviews are designed to provide a broad overview of evidence. Indications for a scoping review are to identify the types of evidence available, clarify key concepts or definitions, examine how research is conducted on a certain topic, and to identify key characteristics related to a concept (Munn et al., 2018). While scoping reviews follow systematic and transparent methods they do not usually include a quality assessment process as the purpose is not to assess the strength of the evidence, but rather to identify and examine the extent of available literature, such as key concepts, types, and sources of evidence. This typology was considered the best fit for this review. The review protocol was uploaded to osf.io on 11 December 2023 (M. Smith et al., 2023) and the search was undertaken immediately thereafter.

2.2. Eligibility

To be eligible, studies needed to focus on links between urban density and child health. All study types were eligible (e.g., cross-sectional, intervention, descriptive), and studies in English of any design (e.g., using qualitative, quantitative, or mixed methods), of any year, or of any type (e.g., peer reviewed articles, conference proceedings, reports, reviews) were all eligible for inclusion in the review. The inclusion of conference proceedings and reports is consistent with scoping review methods (Peters et al., 2021) and is in keeping with previous scoping reviews on child health (e.g., see Martin et al. (2023)). This is a useful approach to uncover up-to-date evidence that may not yet be published in peer-reviewed journals, recognising the considerable time the publication process takes (Barczynski et al., 2009; Ma et al., 2023). Our review criteria were kept deliberately broad, in recognition of children's everyday experiences of urban settings and the diverse contexts children engage with around the world (Martin et al., 2023). For the purposes of this review, children were defined as those aged 0–18 years (Convention on the Rights of the Child, n.d.). Any study not involving participants aged from 0 to 18 years old were excluded. Studies did not need to be stratified for this age group (e.g., studies involving participants aged 10–34 years were eligible). As children are the target population, studies focusing on adults or young adults, even where the age range started at 18 years old, were not eligible.

2.3. Information sources

Searches were conducted in Scopus, a multidisciplinary abstract and citation database that covers various fields, including social sciences, medicine, engineering, and environmental studies. Scopus was identified as the sole database of interest, as it indexes a wide array of journals across the topic areas of interest (n = 1099 in geography, n = 502 in paediatrics and child health, n = 934 in public health), including key journals of relevance to the topic area and where previous reviews had been published (e.g., *Children's Geographies, Journal of Urban Health, Health and Place, BMC Public Health, Pediatric Clinics of North America, Annual Review of Public Health*, The Lancet journals [including *Planetary Health, Child and Adolescent Health, and Global Health*], etc.). We interrogated the indexed journals of other potential databases (including APA PsycInfo and PubMed); none of these databases indexed all the key journals of interest. This was likely due to their narrower areas of focus (e.g., psychological science, biomedicine) compared with the multidisciplinary focus of Scopus, which aligned with this review's focus (encompassing environmental science and urban design, geography, and health). Overall, the use of Scopus enabled an efficient review process that still provided a comprehensive overview of the breadth of research conducted in this field, aligning with the purpose of this scoping review.

2.4. Search strategy

Title, abstract and keyword searches were conducted using the keywords outlined in Table 1. Boolean terms, wildcards, and proximity indicators were used to optimize the search sensitivity and specificity. Keywords were identified from previous reviews and in consultation with topic and library experts. Searches were limited to English language only, and no date limits or other limits were set. Test searches were employed to refine the search and improve its sensitivity and specificity. The final search strategy is outlined below:

(TITLE-ABS-KEY("urban density" OR "compact city" OR "urban intensity" OR "urban growth" OR "neighb*rhood density" OR "city growth" OR "eco cit*" OR "garden cit*" OR ″15 min* neighb*rhood" OR ″20 min* neighb*rhood" OR "urban intensification" OR "urban compactness" OR "urban densification" OR "urban consolidation" OR "population density" OR "residential density" OR "compact urban form" OR urbani*ation or "human density") AND TITLE-ABS-KEY(child*) AND TITLE-ABS-KEY(("physical health" OR "mental health" OR well-being OR wellbeing OR wellness OR vitality OR "quality of life" OR "physical fitness" OR "life satisfaction" OR happiness OR happy) OR (child* W/2 development)))

2.5. Selection of evidence

All titles and abstracts of identified articles were screened by LD, and a random 10% were duplicate screened by PB. Any differences of opinion were resolved by consensus. Four relevance assessment stages were initiated to ensure appropriateness (see below). Studies were excluded in a stepwise fashion starting with titles and abstracts and progressing to full-text screening if any of the inclusion or exclusion criteria were unclear from the title and abstract. Articles were excluded at any stage of the review if they:

1. Did not include children in their study (as defined in the eligibility criteria).
2. Did not include a health or wellbeing measure (e.g., health, wellbeing, quality of life, happiness, vitality, fitness) as defined using the search terms in Table 1.
3. Did not include a measure of urban density. Considering contextual differences in how urban density is defined internationally, urban density was broadly defined using the search terms in Table 1 and was conceptualised as an overall characteristic of an area, rather than specific features of that area. To be included, studies needed to focus on urban density at the area/community, rather than household scale. For example, studies at the neighbourhood, town, city, or

Table 1
Search categories and keywords used in this review.

Category	Environment	Population	Outcome
Search terms	15 min* neighb*rhood 20 min* neighb*rhood city growth compact city compact urban form eco cit* garden cit* human density neighb*rhood density population density residential density urban compactness urban consolidation urban densification Urban density Urban growth urban intensification urban intensity urbani*ation	child*	child* W/2 development happiness happy life satisfaction mental health physical fitness physical health quality of life vitality well-being wellbeing wellness

region, were eligible, while studies looking at household characteristics were excluded. We recognise the limitations of using an area-level, rather than individual-level approach, including the modifiable area unit problem (Openshaw, 1984) and uncertain geographic context problem (Kwan, 2012). In our preliminary searches we identified two large and distinct strands of research – one that focused on area-level concepts of urban density and the other that focused on individual-level measures of density, usually using geographic information systems (GIS)-derived measures of residential and/or population density. Reflecting this, previous reviews have focused solely on GIS-based environmental measures for example in studies of neighbourhood environments and children's physical activity (M Smith, Cui, et al., 2021) and have also highlighted discrete issues when using GIS in this field (Whitehead et al., 2021). Given the scope and aim of this literature review, we prioritised taking a first step to explore broad patterns in links between urban density and child health. This macro-level approach can help policymakers and practitioners understand patterns for future research and will lay the foundation for future work in this area (including future exploration of GIS-based approaches in relation to specific health outcomes.

4. Did not investigate the association (whether quantitative, qualitative, or descriptive) between urban density and child health.

Studies were excluded in a stepwise fashion using the above criteria. Full-text articles were screened if any of these criteria were unclear from the abstract.

2.6. Data charting process and data items

To map the trends and trajectories of literature, a study-specific data extraction chart was generated to capture information on: general study characteristics; participant characteristics; descriptive information about the measurement of urban density applied; study geography; health or wellbeing measure' and key results (Supplementary information). All data for included articles was extracted by LD into an Excel spreadsheet and a random 10% cross-checking of extraction was conducted by MS. No changes were required as a result of the cross-checks.

2.7. Critical appraisal

Quality assessment of literature is not an essential component of scoping reviews. In this review, we anticipated literature to be heterogeneous in focus and methods. Accordingly, we did not undertake quality assessment due to concerns that this approach might lead to inaccurate conclusions that literature was of a higher or lower quality. Rather, our focus was to ensure quality via relevance - adopting a robust relevance assessment criteria for inclusion or exclusion of studies.

2.8. Data synthesis

We generated descriptive overviews for study characteristics, with a focus on understanding how density had been measured and defined in included studies. We used a textual narrative synthesis approach to develop structured summaries (Barnett-Page and Thomas, 2009) in

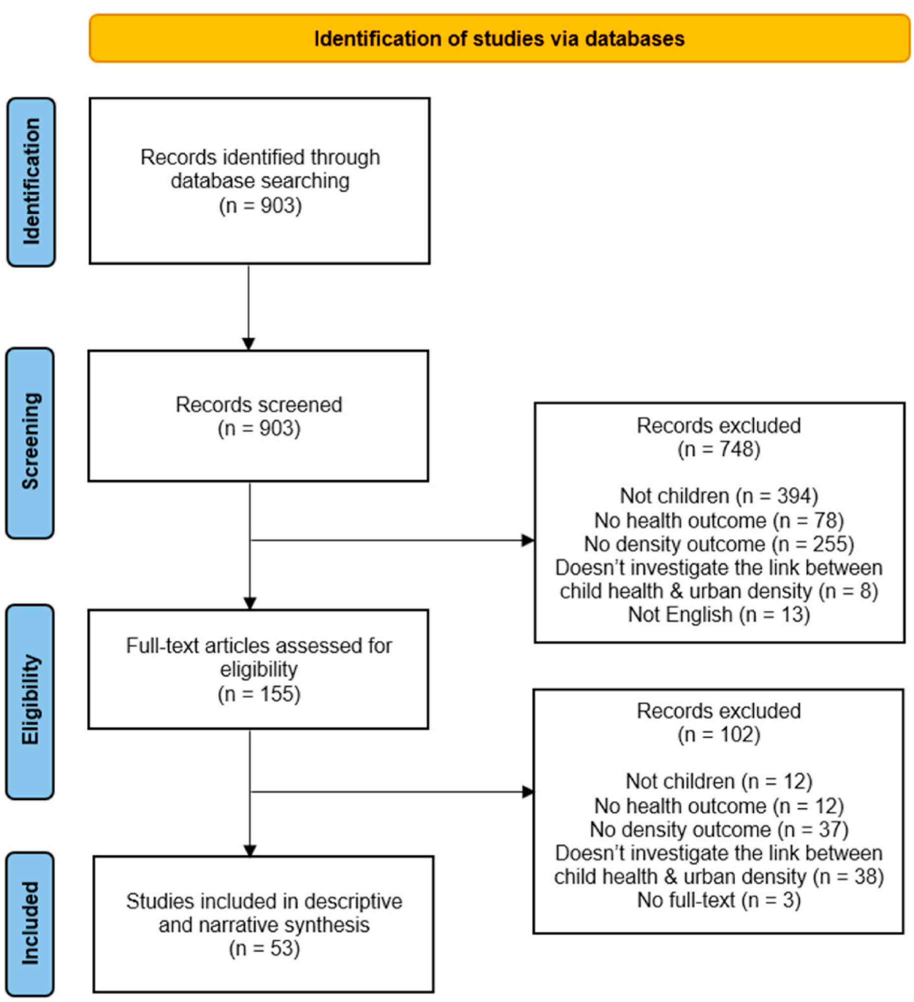

Fig. 1. PRISMA flowchart of study selection process.

relation to the research questions; specifically focusing on descriptions of links or any associations made between urban density and child health, consideration of differences in these relationships by geography, and any measures employed. The results and findings are discussed in the subsequent sections.

3. Results

3.1. Study selection

Fig. 1 shows the flowchart of this review's screening and selection process. The database search resulted in 903 records. Following abstract and keyword screening, 748 studies were excluded, yielding 155 studies for the full-text review. Finally, a total of 53 articles met the inclusion criteria for descriptive and narrative synthesis.

3.2. Study characteristics

The first step in undertaking this scoping review was to examine the general patterns of reviewed literature based on chronology, geography and health domain associated with research on urban density and child health and wellbeing.

Key characteristics of the 53 included studies are provided in Table 2. The publication years ranged from 1972 to 2023, with most articles (n = 44, 83%) published between 2005 and 2023. Of the 53 studies identified, the majority were cross-sectional (n = 37, 70%), followed by longitudinal/cohort study designs (n = 8, 15%). Three studies adopted cross-sectional and longitudinal designs, while the remaining five used time series data. Most articles (n = 45, 85%) included information from a single country, with a total of 30 countries being represented. Data from two papers were collected from multiple European countries (Czechoslovakia, France, Germany, Greece, Iceland, Lithuania, Norway, Spain, and The United Kingdom), while two other studies were carried out across Africa (South Africa and Sub-Saharan Africa). The remaining four studies focused on countries spanning multiple continents; with the number of countries varying from 14 to 141 and the participant numbers ranged from 73 to 8.6 million children. Studies employing a cross-sectional design or using time series data from multiple countries frequently had larger participant numbers. Fifty studies included children aged 0–18, one study included participants aged 10–24, and the other two studies did not specify the age range of the children. These two studies were included as it was clear the population of focus was children: Wardani and Wahono (2020) focused on childhood tuberculosis, and Sharma et al. (2023) focused on child growth. Health outcomes were assessed based on a wide range of dimensions. To aid in result synthesis, this review broadly grouped the studies into six main categories or health domains: i) growth and nutritional status (n = 15, 28%), primarily assessing body size, malnutrition, and identifying signs of inadequate nutrition (e.g., height, weight, vitamin A deficiency, stunting); ii) physical health (n = 11, 21%), focusing on physical capabilities and body functioning (e.g., physical fitness, axial length, oral health); iii) mental health and wellbeing (n = 9, 17%), focusing on emotional and mental state and overall wellbeing (e.g., stress, depression, mood and feelings, quality of life); iv) development (n = 14, 26%), encompassing a child's overall progress (e.g., physical growth, cognitive development, emotional maturity, language skills, social development), and any developmental disorders (e.g., autism); v) lifestyle behaviour (n = 8, 15%), focusing on daily habits and activities that can influence health (e.g., physical activity, sedentary behaviour); and vi) other health outcomes (n = 3, 6%) including mortality, infectious diseases, immunization status. No studies considered the domain of social health (e.g., social cohesion).

3.3. How has urban density been measured in studies of child health?

Urban density showed substantial variation in both its conceptualisation and measurement. Over one-third of the studies (n = 19, 36%) used categories for urbanisation or density without providing a clear definition. We considered these studies as implying higher versus lower degrees of density in their area categorisations, and thus these studies were included in this review. Sixteen of these 19 studies adopted urban-rural categories, while the remaining three were (i) urban formal-urban informal-rural, (ii) urban slum-general urban, and (iii) village-city-town categories. Definitions were not accompanied by in-depth rationale or problematisation of these concepts.

Seventeen studies (32%) provided descriptions of urban density measures. Of these, five studies employed population density as an indicator of urban density, using a continuous measure of the number of people per unit area (across a range of different units, e.g., people/km^2, people/m^2) (Balk et al., 2005; Fathmawati et al., 2023; Marquez et al., 2023; Prado-Galbarro et al., 2021; Zhou et al., 2022). A further three of the 17 studies quantified building density to assess residential density (Collyer et al., 2022; Fernández-Barrés et al., 2022; Torun et al., 2022; Collyer et al., 2022 quantified the number of dwellings within 10 m^2 of residential land area. Fernández-Barrés et al. (2022) primarily looked at the horizontal extent of building cover by calculating the ratio of building footprint to the total area of the neighbourhood, Torun et al. (2022) considered both horizontal (building footprint) and vertical (number of stories) dimensions by multiplying the building footprint by the number of stories and then dividing by the total area. Fernández-Barrés et al. (2022) utilized population density alongside building density to evaluate urban density. Of the 17 studies, nine used urbanisation to indicate urban density; however, the ways in which authors conceptualised urbanisation varied significantly. Inoue, Howard, Thompson, and Gordon-Larsen (2018) and Y. Zhang et al. (2019) applied a 12-component urbanisation index (*economic activity, traditional market, modern market, population density, transportation, sanitation, housing, health infrastructure, education, social services, communications,* and *diversity*) to capture the level of urbanisation in China; while Weiss, Dang, Lam, and Nguyen (2020) assessed the urbanisation level in Vietnam by considering four factors: crime, cleanliness, social evils, and neighbour support. Four of the 17 studies expressed urbanisation as the percentage of the population residing in a city/town or urban area (Argaw et al., 2019; Dong et al., 2019; Paciorek et al., 2013; Terra De Souza et al., 1999). Notably, one study utilized two remote sensing data, impermeable surface area, and night-time luminosity, to standardise the urban measurement across Sub-Saharan countries (Ru et al., 2022). Lastly, Squillacioti et al. (2023) defined urbanisation level based on land-use coverage; the less urbanised area was characterised by a high correlation with vegetation vigour and agricultural and forest coverages, whereas more urbanised areas displayed the opposite trend.

In the remaining 17 studies defining density, authors included descriptions of urban density or urbanisation and classified them into different thresholds. Eight studies measured population density as the number of people per square kilometre, seven relied solely on population size to categorise areas without accounting for land area, and two classified urbanisation by the density of addresses per square kilometre. Sharma et al. (2023) incorporated night-time light data, in addition to population size, as an indicator of urbanisation. Although the measurement methods might be similar, the classification schemes differed across settings, even among studies conducted within the same country, indicating that approaches may be relative to the country, but also relative to the area of study. To illustrate the differences in classification schemes internationally, in Norway, 1650 residents/km^2 was considered high density (Nordbø et al., 2019, 2020), whereas high density was defined as 7501 residents/km^2 in Indonesia (Wardani and Wahono, 2020), 10,000 people/km^2 in Japan (Sato et al., 2018), and 30,000 people/km^2 in Hong Kong and South Korea (Choi et al., 2017; Choo et al., 2017) - demonstrating significant variation between European and South East Asian contexts. Similarly, in France, Egypt, and Denmark, the most urbanised areas were classified as having populations exceeding 10,000, 50,000, and 100,000 people, respectively (Brink et al., 1983;

Table 2
Characteristics of studies included in this review, grouped by health domain and ordered chronologically (most recent to least recent).

Health Domain:	Lead author (year)	Country of origin; ecological level of study	Aim	Study design	Participant number/Age; Primary respondent	Measurement of urban density	Measurement of health or wellbeing outcome	Key findings
Child Growth and Nutritional Status	Sharma et al. (2023)	India; Urban and rural	Examined how the level of urbanization influences explanatory variables of child growth. Analyse how different types of urban settlements affect child growth prevalence in India.	Cross-sectional	n = 38470 Age not reported; Respondent not reported	Night-time light as a proxy variable for urbanization: dark (0–1.72 nWcm−2 sr−1), medium(1.72–3.63), bright (3.63–5.35), brightest (>4.34) Urban settlement categories: town (5000–100,000 inhabitants), city (100,000–1 million), million plus city (1 million - 10 million), megacities (>10 million).	Height-for-age z-scores	Urbanization was associated with a reduction in child stunting. The prevalence of child growth is slowest at the highest level of urbanization. Urbanization improves child growth outcomes across all urban settlements except towns. Increasing level of urbanization showed a decrease in child growth rate from all wealth groups except middle and rich households.
	Marais et al. (2022)	South Africa; Urban and rural	Investigated whether an urban premium or penalty exists for children by comparing child stunting across three settlement categories: urban formal, urban informal and rural.	Cross-sectional	n = 12304, 6 months - 14 years; Respondent not reported	3 settlement categories: urban formal, urban informal (unplanned) and rural.	Z-score for height-for-age of two or more standard deviations below the median height for their age	Children in formal urban areas were significantly less stunted than those in rural areas. However, there is little difference between children in urban informal areas and rural areas.
	Ru et al. (2022)	Sub-Saharan Africa; Urban and rural	Examined the relationship between urbanization and a key dimension of wellbeing across Sub-Saharan Africa: child growth failure, including (i) low growth; (ii) wasting; and (iii) underweight.	Time series data	n not reported 0–5 years; Respondent not reported	Level of urbanization based on 2 remotely sensed databases: 1. A land cover measure of impermeable surface area, obtained from the Global Artificial Impervious Areas. 2. A luminosity measure of nightlights— a key indicator of human settlements and economic.	Height-for-age z-score Weight-for-age z-score Weight-for-height z-score	Urbanization was associated with better child growth outcomes, by reducing low growth, wasting, and underweight at both country and region levels.
	Shah et al. (2020) [a]	Malaysia; Urban and rural	Investigated the differences on stress and eating behaviour of adolescents in urban and rural areas.	Cohort	n = 797, 16 years; Child (stress, eating behaviour) and trained staff (height, weight)	Area categories: urban and rural	Height and weight	Urban adolescents had a higher prevalence of stress, obesity and overweight compared to rural adolescents. Urban adolescents are less healthy compared to rural adolescents when dealing with stress.
	Argaw et al. (2019)	Bangladesh, Cambodia, Ethiopia, Haiti, Kenya, Malawi, Mali, Nepal, Nigeria, Rwanda, Tanzania, Uganda, Zambia, and Zimbabwe; Urban and rural	Examined the association between changes in a range of distal to proximal factors and stunting prevalence among children under-five years of age.	Pooled data from 50 demographic surveys	n = 322320, 28.6 ± 17.2 months; Respondent not reported	Urbanization was calculated as percentage of total population living in urban areas.	A height/length-for-age z score below 2 standard deviations from the median based on the WHO 2006 Child Growth Standards	Increasing urbanization was significantly associated with a lower probability of growth-stunting within a country for children under-five.

(*continued on next page*)

Table 2 (*continued*)

Health Domain:	Lead author (year)	Country of origin; ecological level of study	Aim	Study design	Participant number/Age; Primary respondent	Measurement of urban density	Measurement of health or wellbeing outcome	Key findings
	[illegible]	China; Urban and rural	Investigated the [illegible] [illegible] [illegible] ratio (WHtR) of Chinese children from 1993 to 2011.	[illegible] sectional	n = [illegible], [illegible] years; Trained staff	[illegible]	[illegible] used WHO Growth Reference 2007	[illegible] Furthermore, population density had a significant positive association with the height of older children aged 13–18 years.
	Paciorek et al. (2013)	141 countries; Urban and rural	Investigated trends in children's height and weight in rural and urban settings.	Time series data	n = 8.6 million, 0–5 years; Respondent not reported	Urbanization is defined as an increase in the proportion of a country's population living in cities. Area categories: urban and rural.	Height-for-age and weight-for-age z scores (followed 2006 WHO growth standards)	Urban children are taller and heavier than their rural counterparts in nearly all countries.
	Van de Poel, O'Donnell, and Van Doorslaer (2007) [a]	47 developing countries: Sub-Saharan Africa, Near East, South & Southeast Asia, Latin America & Caribbean; Urban and rural	Present the magnitude and explanation of rural–urban disparities in child health throughout the developing world.	Cross-sectional	n not reported 0–5 years; Respondent not reported	Area categories: urban and rural	Low growth is defined as child's height falls two standard deviations below the median height of children of the same age and gender in a 'healthy' reference population	On average, children in rural areas had 1.4 times higher risk of low growth and under-5 mortality. Despite the same median relative risk, urban-rural disparities in growth-stunting and under-5 mortality are not strongly correlated across countries and regions.
	Izutsu et al. (2006) [a]	Bangladesh; City	Compared adolescents' quality of life (QOL), mental health, and nutritional status in non-slum and slum areas.	Cross-sectional	n = 602, 11–18 years; Child (QOL, mental health) and trained staff (weight, height)	Area categories: urban slum and non-slum. Urban slum: an area that has inadequate access to safe water; inadequate access to sanitation and other infrastructure; poor structural quality of housing; overcrowding; and insecure residential status. Non-slum areas: general urban residential areas.	Weight and height measurement	For nutritional status, adolescents residing in slums had a significantly lower weight and BMI than those not residing in slums. Quality of life scores of adolescents residing in slums were significantly worse than their peers living outside of slums. However, most of the mental health indexes were better in adolescents residing in slum areas.
	Balk et al. (2005)	Phase I: 19 African countries Phase II: 45 countries across Africa, Asia and Latin America; Urban and rural	Examined the effects of geographic and environmental variables on child hunger at both household and regional levels.	Cross-sectional	n not reported 1–3 years; Respondent not reported	Population density is described as in person per km2 of land area.	Weight-for-age and height-for-age Z scores	In the analysis of 19 African countries, population density was weakly associated with children not being underweight. Overall analysis of 45 countries in Africa, Asia and Latin America showed that high

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Health Domain:	Lead author (year)	Country of origin; ecological level of study	Aim	Study design	Participant number/Age; Primary respondent	Measurement of urban density	Measurement of health or wellbeing outcome	Key findings
								density levels were associated with higher levels of children underweight. Children in urban areas are less underweight than rural children.
	Terra De Souza et al. (1999)	Brazil; Municipalities	Examined the relative contribution of behavioural, health service, and socio economic variables to variations in the prevalence of inadequate weight gain in infants and young children.	Cross-sectional	n not reported 0–23 months; Trained staff	Percentage urbanization is calculated as the proportion of the population living in urban area.	Weight was recorded based on the NCHS/WHO reference growth curves	Percentage urbanization significantly predicts inadequate weight gain in infants and children. Municipalities with a higher percentage of urban population had a lower prevalence of inadequate weight gain.
	Wojnicz et al. (1991)	Poland; Urban and rural	Evaluated the relationship between child development and environmental factors in male population of vocational mining schools in the Lublin Coal Basin.	Cross-sectional	n = 893, 4–17 years; Trained staff	Area categories: village, city, town	Height, body mass and Quetelet index	Boys living in cities had higher indicators of child development (height, body mass, and Quetelet index) compared to the boys in villages and country areas.
	Brink et al. (1983)	Egypt; Urban and rural	Assessed the nutritional status of Egyptian children and compared the nutritional status of children between rural and urban populations.	Cross-sectional	n = 9794, 6–71 months; Trained staff	Urbanization classifications: Rural universes (<10,000 residents), a large village universe (10,000–49,999 residents), a small town universe (10,000–49,999 residents), and a small city universe (>50,000 residents).	Length, weight, firm thumb pressure; detected vitamin A and D deficiency; collected capillary blood and haemoglobin content	The prevalence of severe malnutrition and anaemia in children decreased as urbanization increased.
	Clark (1980)	The Kingdom of Tonga; Urban and rural	Examined the urban-rural differences in nutritional status among preschool children.	Cross-sectional	n = 265, 2–5 years; Trained staff	Area categories: urban and rural	Anthropometric measurements	Children in rural areas had higher height and weight, as well as better physical growth and development compared to children in urban areas.
Physical Health	Tian et al. (2021) [a]	China; Urban and rural	Examined urban-rural differences in physical fitness and out-of-school physical activity for primary school students. Explored the correlation of physical fitness and out-of-school PA for primary school students in urban and rural areas.	Cross-sectional	n = 715, 8–13 years; Child (physical activity) and teacher (physical fitness)	Area categories: urban and rural	Physical fitness was measured using the 2014 version of the Chinese Student Physical Fitness Standards	Urban school students had a significantly lower physical fitness index and weekly out-of-school physical activity duration compared to students in rural areas.
	Dong et al. (2019)	China; Urban and rural	Assessed secular trends in the physical fitness and its association with the nutritional transition among Chinese children and	Longitudinal	n = 1494485, 7–18 years; Trained staff	The urbanization level was expressed as the percentage of the permanent population of cities and towns within the total recorded	Forced vital capacity, standing long jump, sit-and-reach, body muscle strength, 50-m dash, and endurance running	From 10 to 90% urbanization, physical fitness indicator (PFI) for children and adolescents decreases as urbanization

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Health Domain:	Lead author (year)	Country of origin; ecological level of study	Aim	Study design	Participant number/Age; Primary respondent	Measurement of urban density	Measurement of health or wellbeing outcome	Key findings
			adolescents. Explored the effects of urbanization on physical fitness.			population in a province at some point in time.		increases. Child and adolescent FPI was still increasing in areas with urbanization lower than 40%, but declined with further urbanization.
	Choi et al. (2017)	Hong Kong; City	Investigated whether residing in more crowded habitats in Hong Kong is associated with refractive error among children.	Cross-sectional	n = 1075, 7–12 years; Clinician	The districts were divided into three clusters according to their population densities: high (>30,000 persons per km2), medium (10,000–30,000 persons per km2), low (<10,000 persons per km2).	Ocular axial length (AL) and Spherical equivalent refraction (SER) status; AL was measured using partial coherence interferometry SER was evaluated by non-cycloplegic open-field auto-refraction	High population density was associated with children's axial length and childhood refractive error.
	Lo et al. (2017) [a]	Taiwan; Urban and rural	Investigated the association of school environment and after-school physical activity with health-related physical fitness in Taiwanese adolescents.	Cross-sectional	n = 649442, 13–15 years; Trained staff	Area categories: urban and rural	Muscle strength and endurance, explosive power, flexibility, and cardiorespiratory endurance; body composition	Urban adolescents perform better in most of the physical fitness measurements (muscle strength and endurance, cardiorespiratory endurance, flexibility, and explosive power) compared to rural adolescents.
	Castillo et al. (2016)	Kenya; Urban and rural	Studied the effects of urbanization on physical fitness (PF) by comparing PF between urban and rural children.	Cross-sectional	n = 115, 6–17 years; Trained staff	Area categories: urban and rural	Physical fitness assessed by FITNESSGRAM tests	There were no significant differences in overall physical fitness between urban and rural children. While there was no difference in measures of strength or flexibility, rural children had a better endurance performance than their urban counterparts.
	Machado-Rodrigues et al. (2014) [a]	Portugal; Urban and rural	Compared physical activity, physical inactivity, time spent in screen related sedentary activities and cardiorespiratory fitness in rural and urban adolescents.	Cross-sectional	n = 362, 13–16 years; Trained staff	Urban areas were defined as a city with >500 inhabitants/km2 or >50,000 inhabitants. Rural areas were defined as villages with≤100 inhabitants/km 2 or with the total population <2000 people.	Cardiorespiratory fitness was assessed by the Progressive Aerobic Cardiovascular Endurance Run test	Urban boys and girls spent less time in sedentary activities than their rural counterparts. Rural boys and girls had higher levels of cardiorespiratory fitness than their peers in urban areas. Boys in rural areas were less active in moderate-to-vigorous physical activity (MVPA) than boys in urban areas, particularly on weekends. Unlike boys, urban adolescent girls spent significantly less time in

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Health Domain:	Lead author (year)	Country of origin; ecological level of study	Aim	Study design	Participant number/Age; Primary respondent	Measurement of urban density	Measurement of health or wellbeing outcome	Key findings
								MVPA than adolescent girls in rural areas.
	Ujević et al. (2013) [a]	Croatia; Urban and rural	Examined the differences between children's health physical fitness profiles in urban and rural areas.	Cross-sectional	n = 2431, 11.3 ± 6.1 years; Trained staff	Area categories: urban and rural	American Alliance for Health, Physical Education, Recreation and Dance test battery (AAHPERD); anthropometric measures	Urban children performed significantly better in the 20m dash, standing long jump and timed sit-ups than rural children, who had better results in the distance run. There is no significant difference in the flexibility, body mass index, and body fat percentage between children from urban and rural areas.
	Tinazci and Emiroğ;lu (2010) [a]	The Turkish Republic of North Cyprus; Urban and rural	Revealed the differences in physical fitness levels between rural and urban children.	Cross-sectional	n = 7417, 9–11 years; Trained staff	Area categories: urban and rural	The European physical fitness test battery (EUROFIT)	Children in urban areas had higher body fat, lower flexibility, muscle endurance and strength levels than peers in rural areas.
	Silburn et al. (2007) [a]	Australia; Urban and rural	Examined the health and well-being of Aboriginal and Torres Strait Islander children and adolescents. Identified the developmental and environmental factors supporting child development.	Cross-sectional	n = 1480, 12–17 years; Child and parent	Area categories: urban and rural	Survey of health indicators (oral health, asthma)	Aboriginal young people in areas of the highest urbanization had a 5 times higher prevalence of asthma than those in extremely remote areas. Living in more urbanised settings showed poorer oral health for Aboriginal and Torres Strait Islander children and adolescents. Young people in metropolitan areas had a higher prevalence of mental health problems compared to those in areas of extreme isolation.
	Rutenfranz et al. (1982) [a]	Czechoslovakia, Germany, Iceland, Norway; Urban and rural	Tested the hypothesis that children of urbanised societies are hampered in their functional growth compared to rural living children.	Cross-sectional and longitudinal	n not reported 8–18 years; Trained staff	Area categories: urban and rural	Cycle ergometer test	In Norway and Iceland, urban children had a stronger exercise fitness than children in rural areas. In Czechoslovakia and West Germany, there is no significant difference in exercise fitness between children residing in urban or rural areas.
	Yoshizawa (1972)	Japan; Urban and rural	Compared the endurance capacity of urban and rural adolescents and related the results to ecological factors	Cross-sectional	n = 1291, 9–17 years; Trained staff	Area categories: urban and rural	Ergometer load bearable at a heart rate level of 170 beats/min (PWC170) and maximum oxygen uptake (VO^2max)	From the age of 15, rural adolescents had a significantly higher PWC170 and VO2 max values.

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Health Domain:	Lead author (year)	Country of origin; ecological level of study	Aim	Study design	Participant number/Age; Primary respondent	Measurement of urban density	Measurement of health or wellbeing outcome	Key findings
			affecting aerobic work capacity.					
Mental Health and Wellbeing	Marquez et al. (2023)	England; Metropolitan area	Examined the influence of neighbourhoods on loneliness in early-to-mid adolescence.	Cross-sectional	n = 36141, 12–15 years; Child	Population density was calculated as the number of people per square kilometre.	The Office for National Statistics (ONS) single-item loneliness measurement	In the demographic domain, higher population density was associated with lower levels of adolescent loneliness.
	Torun et al. (2022)	Turkey; City	Investigated the association of children's local neighbourhoods and their mental wellbeing.	Cross-sectional	n = 163, 9–12 years; Child	Building density was defined as total built-up area (i.e., building footprint multiplied by the number of stories) per unit of home neighbourhood area.	Me and My Feelings Survey (Deighton et al., 2013) and Students' Life Satisfaction Scale (Huebner, 1991)	Building density within the home environment did not show any association with children's mental wellbeing and life satisfaction.
	Chen et al. (2021)	China; Urban and rural	Investigated the gender and regional differences in depressive traits among adolescent students.	Cross-sectional	n = 2137, 10–15 years; Child	Area categories: urban and rural	The standard Center for Epidemiological Studies Depression Scale (CES-D)	Rural adolescent students had higher levels of anhedonia compared to their urban counterparts, but the effect size of this difference was small.
	Nordbø et al. (2020)	Norway; Urban and rural	Examined the direct associations between some built environment characteristics (i.e., population density, green space and facilities) and children's subjective well-being. Assessed whether and how participating in different leisure activities mediate the relations between built environment characteristics and children's subjective well-being	Cross-sectional	n = 23043, 8 years; Mother	Population density was calculated as the total number of residents per square kilometres within the buffer zone (800m radius). There are 4 categories: ≤200 residents (reference), 201–799 (low), 800–1649 (moderate) and ≥1650 (high).	Norwegian version of the Short Mood and Feelings Questionnaire (SMFQ)	Living in a more densely populated area was negatively associated with children's subjective well-being. However, living in more densely populated areas indirectly increased children's moods and feelings through greater involvement in organized and social activities.
	Shah et al. (2020) [a]	Malaysia; Urban and rural	Investigated the differences on stress and eating behaviour of adolescents in urban and rural areas.	Cohort	n = 797, 16 years; Child (stress, eating behaviour) and trained staff (height, weight)	Area categories: urban and rural	Cohen Perceived Stress Scale (CPSS) Questionnaire	Urban adolescents had a higher prevalence of stress, obesity and overweight compared to rural adolescents. Urban adolescents are less healthy compared to rural adolescents when dealing with stress.
	Bui et al. (2018)	Vietnam; Urban and rural	Analysed the trajectories of depression among the youth during the 2006–2013 period, and identified factors associated with youth depression.	Longitudinal	n = 2215, 10–24 years; Child	Area categories: urban and rural	The Center for Epidemiological Studies Depression Scale (CES-D)	Urban youth had a higher mean depression score compared to rural youth.
	Adriaanse et al. (2014)	Netherlands; Urban and rural	Investigated to what extent differences in prevalence and types of mental health	Cross-sectional	n = 1278, 12.9 ± 1.8	The urbanization is the average density of addresses per square kilometre.	The Strengths and Difficulties Questionnaire (SDQ)	Living in an urban neighbourhood was significantly related to high

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Health Domain:	Lead author (year)	Country of origin; ecological level of study	Aim	Study design	Participant number/Age; Primary respondent	Measurement of urban density	Measurement of health or wellbeing outcome	Key findings
			problems between ethnic minority youth and majority youth can be explained by social disadvantage.		years; Child and teacher	There are 3 categories: rural (<1000 addresses per km2), intermediate (1000–1500 addresses per km2), urban (>1500 addresses per km2).		mental health problems in all ethnic groups for ethnic minority youth.
	Silburn et al. (2007) [a]	Australia; Urban and rural	Examined the health and well-being of Aboriginal and Torres Strait Islander children and adolescents. Identified the developmental and environmental factors supporting child development.	Cross-sectional	n = 1480, 12–17 years; Child and parent	Area categories: urban and rural	Goodman's Strength and Difficulties Questionnaire (SDQ)	Aboriginal young people in areas of the highest urbanization had a 5 times higher prevalence of asthma than those in extremely remote areas. Living in more urbanised settings showed poorer oral health for Aboriginal and Torres Strait Islander children and adolescents. Young people in metropolitan areas had a higher prevalence of mental health problems compared to those in areas of extreme isolation.
	Izutsu et al. (2006) [a]	Bangladesh; City	Compared adolescents' quality of life (QOL), mental health, and nutritional status in non-slum and slum areas.	Cross-sectional	n = 602, 11–18 years; Child (QOL, mental health) and trained staff (weight, height)	Area categories: urban slum and non-slum. Urban slum: an area that has inadequate access to safe water; inadequate access to sanitation and other infrastructure; poor structural quality of housing; overcrowding; and insecure residential status. Non-slum areas: general urban residential areas.	The World Health Organization Quality of Life Assessment Instrument	For nutritional status, adolescents residing in slums had a significantly lower weight and BMI than those not residing in slums. Quality of life scores of adolescents residing in slums were significantly worse than their peers living outside of slums. However, most of the mental health indexes were better in adolescents residing in slum areas.
Child Development	Fathmawati et al. (2023)	Indonesia; City	Determined the number of children with autism and to map its distribution in Pontianak.	Cross-sectional	n = 83, 2–18 years; Clinician	Population density per km2.	Medical records from Pontianak Psychiatry Hospital and registration at Disability and Assessment Centre Service from 2015 to 2020	The distribution patterns of autism in children was clustered in densely populated areas.
	Collyer et al. (2022)	Australia; Metropolitan areas	Identified features of the built environment that are differentially associated with early childhood development within the context of broader socioeconomic factors.	Cross-sectional	n = 24036, Average 5.4 years; Teacher	Dwelling density refers the number of residential dwellings per 10 m2 of residential land area.	The Australian Early Development Census score	In high social economic status (SES) neighbourhoods, higher residential density was associated with better physical, social and emotional development in early childhood. In low SES neighbourhoods,

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Health Domain:	Lead author (year)	Country of origin; ecological level of study	Aim	Study design	Participant number/Age; Primary respondent	Measurement of urban density	Measurement of health or wellbeing outcome	Key findings
								higher residential density was associated with better physical, but poorer social and emotional development in early childhood.
	Prado-Galbarro et al. (2021)	Mexico; Urban municipalities	Explored how the social and built environment in urban municipalities are associated with overall early child development (ECD) and its specific domains in Mexico.	Cross-sectional	n = 2194, 36–59 months; Mother	Urban growth measures of the size and density of the area (inhabitants per km2).	The Early Childhood Development Index explores four domains of development (literacy-numeracy, physical, socio-emotional, and learning), developed by UNICEF	Higher population density was associated with higher odds of inadequate early childhood development in general and specially in the learning domain.
	Dursun et al. (2020)	Turkey; City	Understand the prevalence of childhood psychiatric disorders and subthreshold psychiatric problems from middle-class city centres, city centres in slums, towns and village areas.	Cross-sectional	n = 1080, 8.23 ± 0.77 years; Parent, teacher and child	Area categories: middle-class city centres, city centres in slums, towns and village areas. A town was described as an area with over 5000 people located 5 km from other towns, and a village with a rural population under 5000.	The Development and Well-Being Assessment (DAWBA)	Children living in village areas had a higher prevalence of psychiatric disorders and externalization disorders. Conversely, children living in suburban areas in cities had fewer psychiatric disorders, especially internalization disorders, compared to other human settlement areas.
	Evans et al. (2020)	Netherlands; Municipalities	Examined the effects of current urbanicity and early childhood urbanicity on mental health problems in children directly, and indirectly via hypothalamic-pituitary-adrenal (HPA)-axis functioning.	Cross-sectional and longitudinal	Cross-sectional: n = 306, 7–12 years; Longitudinal: n = 141, 0–7 years; Mother	Urbanicity is calculated using the surrounding address density (SAD) which is a continuous measure indicating the degree of human activity in a given area. It is then coded on a scale from 0 (very rural; SAD <500 addresses per km2) to 4 (very urban; ≥ 2500 addresses per km2).	The Dutch version of the Child Behaviour Checklist (CBCL) 6–18	There was no direct or indirect association between urbanicity and early years behavioural and emotional issues through hypothalamic-pituitary-adrenal (HPA)-axis functioning. In addition, there is no observed effects of urbanicity on HPA axis functioning for children.
	Weiss et al. (2020)	Vietnam; Urban and rural	Assessed relationship between urbanization factors and child mental health in Vietnam.	Cross-sectional and longitudinal	Cross-sectional: n = 1,314, 6–16 years Longitudinal: n = 256, 6–16 years; Parent	Urbanization Factors Questionnaire assess four factors: (a) Crime (e.g., theft from homes or stores); (b) Unclean (physical environment; e.g., pollution; noise); (c) Social Evils (e.g., presence of karaoke bars); and (d) Neighbour Support (e.g., a neighbour with whom one could discuss a personal problem)	Child Behaviour Checklist Brief Impairment Scale	In cross-sectional analyses, higher levels of urbanization were associated with higher levels of child psychopathology and functional impairment. However, the longitudinal analyses showed that level of urbanization did not have a significant impact on child functioning.
	Lauritsen et al. (2014)	Denmark; Mulnicipalitites	Examined the association between urbanicity level and autism spectrum disorders	Cohort	n = 3921, 0–14 years; Clinician	The degree of urbanization with population densities for the capital, capital suburbs, provincial cities,	Had been admitted to a psychiatric hospital or had received outpatient care for a diagnosis of	Higher degree of urbanization, both at birth and during childhood, was associated with higher risk

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			(ASD) at birth and during childhood.			provincial towns, and rural areas respectively of 5220, 845, 470, 180, and 55 people per km2.	ASD, according to the International Classification of Diseases (ICD-8) and (ICD-10)	of autism. Further, moving to a higher level of urbanicity after birth associated with higher risk of autism. Also, diagnosis of autism at an earlier age was observed in urban areas.
	Choo et al. (2017)	South Korea; Municipal county	Identified the factors that are associated with behavioural problems among children in community child centres.	Cross-sectional	n = 175, 6–12 years; Parent	The population density was calculated as the population divided by the district area, grouped into four categories: <10,000, 10,000–19,999, 20,000–29,999, and ≥30,000 persons/km2.	The Child Behaviour Checklist/6–18	A lower density was significantly associated with more behavioural problems (i.e. internalizing subscales, anxiety/depression, social problems, and rule-breaking behaviour) in children at the community centres.
	Gouin et al. (2015)	France; City	Determined the association of urbanicity with cognitive development at five years of age in preterm children who were free of any disabilities or neurodevelopmental delays.	Cohort	n = 1738, <35 weeks; Teacher	The urban unit was used to define the degree of urbanicity of the communes. Three urban unit categories: rural (<2000 people), quasi-rural (2000–9999 people), and urban (10,000–1,999,999 people).	The Global School Adaptation score (GSA)	Urbanicity was significantly associated with cognitive neurodevelopment for children at five years of age. Living in urban or quasi-rural areas was associated with a lower cognitive development compared to living in rural areas.
	Gau et al. (2005)	Taiwan; Urban and rural	Investigated the prevalence and changing trends of mental disorders and the effects of gender and urbanization among adolescents in Taiwan.	Longitudinal	n = 1070, 13–15 years; Child and teacher	Area categories: urban and rural	Chinese K-SADS-E interview and Teacher report form of the Child Behaviour Checklist	Overall, rural adolescents had a higher rate of psychiatric disorders compared to urban adolescents. In particular, rural adolescents had higher rates of conduct disorder, oppositional defiant disorder, and substance use disorders than their urban counterparts.
	Lauritsen et al. (2005)	Denmark; Urban and rural	Investigated the effects of potential risk factors of autism, including place of birth, parental place of birth, parental age, family history of psychiatric disorders, and paternal identity.	Cohort	n = 818, <10 years; Clinician	The degree of urbanization was classified according to capital, capital suburb, provincial city with more than 100,000 inhabitants, provincial towns with more than 10,000 inhabitants, or rural areas.	Had been registered as inpatients or received outpatient care at a psychiatric hospital with the diagnoses childhood autism (ICD-10: F84.0) or atypical autism (ICD-10: F84.1) *children born from 1984 to 1992 followed ICD-8	Among children born 1993 or later, increasing degree of urbanization was associated with higher risk of autism, while there was no clear relationship between degree of urbanization and risk of autism among the cohort of children born 1984–1992. Overall, children born in a capital or suburb had a two-times greater risk of autism than those born in other locations.

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	Al-Ansari and Bella (1998)	Saudi Arabia; Urban and rural	Demonstrated the variations in child development between urban and rural settings.	Cross-sectional	n = 1219, 0–6 years; Mother	Area categories: urban and rural	The Revised Denver Pre-screening Developmental Questionnaire	Children in urban areas develop faster in fine-motor and language abilities; children in rural areas develop faster in gross-motor and personal social abilities.
	Zahner et al. (1993)	United States; Metropolian areas	Assessed the impact of rural-urban residence on the mental health of preadolescent children.	Time series data	n = 2519, 6–11 years; Parent and teacher	Area categories: city (areas of 25,000–40,000 population classified as 100% urban), suburban fringe (areas designated as 1–99% urban), rural (towns classified as 0% urban).	The Child Behaviour Checklist and Teacher's Report Form	Girls in urban areas were reported with higher rates of total disturbance, behavioural disturbance and social withdrawal. For boys in urban areas, there were trends indicating higher rates of emotional disturbance.
	Achenbach et al. (1991)	United States; Urban-suburban-rural	Identified the association between parental reports of children's problems and competencies and various demographic and socioeconomic factors across two groups: i) children assessed at intake to mental health service ii) children assessed through a home interview survey	Cross-sectional	n = 5400, 4–16 years; Parent	4 categories of urbanization: primary sampling units (PSUs) of≥1,000,000 population (most urban); PSUs of 250,000–999,999 population; PSUs of 10,000–249,9999 population; PSUs ranging from unincorporated rural areas to unurbanized areas of 9999 population.	The Achenback, Conners, and Quay (ACQ) Behaviour Checklist	Children in the most urban and rural areas showed similar rates of mental health referrals and problem scores. However, the areas of intermediate urbanization showed significantly higher in referral rate, plus higher problem scores among those not referred to mental health service, compared to the most urban and rural areas. Competence scores were not significantly associated with urbanization.
Lifestyle Behaviour	Squillacioti et al. (2023)	Italy; Town	Investigated the association between urban environment's key characteristics and sedentary behaviour in school-aged children.	Cross-sectional	n = 331, 9–11 years; Parent	Urbanised coverage: less urbanised area are highly and positively correlated with vegetation vigour, agricultural and forest coverages while more urbanised area with urbanised coverage.	Parents were asked to quantify the time spent by their children in computer/internet browsing, playing video games, reading, listening to music, watching television, and talking while sitting, either in person or by phone.	Living in less urbanised areas is associated with lower levels of sedentary behaviour in school-aged children. Children in less urbanised areas showed 15 min less of sedentary time per day and had daily screen time reduced by 14% compared to children in more urbanised areas.
	Fernández-Barrés et al. (2022)	France, Greece, Lithuania, Norway, Spain, UK; City	Evaluated the association between several urban environment indicators and health behaviours in children.	Cross-sectional	n = 1581, 6–11 years; Parent	Building density (within the 300-m buffer) was calculated by dividing the area of building cover (km2) by the area of buffer (km2). Population density was calculated as the number of inhabitants (per km2)	Standardized questionnaires to measure moderate-to-vigorous physical activity, physical activity outside the school hours, sleep duration, sedentary actives and	

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						surrounding the home and the school area.	active transport from home to school	
	Zhou et al. (2022)	China; City	Evaluated the influence of building environment factors on children's independent activities and the connection between parental decision-making and children's permission for independent activities.	Cross-sectional	n = 745, 6–12 years; Trained staff	Population density was defined as the ratio of the number of residents in the radiation radius of the site to the total radiation area.	The total number of physical activities and the type of activities in the sites were counted by observation and behaviour mapping	Among the built environment factors, higher residential population density was positively correlated with children's independent activity.
	Tian et al. (2021) [a]	China; Urban and rural	Examined urban-rural differences in physical fitness and out-of-school physical activity for primary school students. Explored the correlation of physical fitness and out-of-school PA for primary school students in urban and rural areas.	Cross-sectional	n = 715, 8–13 years; Child (physical activity) and teacher (physical fitness)	Area categories: urban and rural	The International Physical Activity Questionnaire (IPAQ) was used to assess physical activity	Urban school students had a significantly lower physical fitness index and weekly out-of-school physical activity duration compared to students in rural areas.
	Shah et al. (2020) [a]	Malaysia; Urban and rural	Investigated the differences on stress and eating behaviour of adolescents in urban and rural areas.	Cohort	n = 797, 16 years; Child (stress, eating behaviour) and trained staff (height, weight)	Area categories: urban and rural	Child Eating Behaviour Questionnaire (CEBQ)	Urban adolescents had a higher prevalence of stress, obesity and overweight compared to rural adolescents. Urban adolescents are less healthy compared to rural adolescents when dealing with stress.
	Nordbø et al. (2019)	Norway; Not reported	Examined whether population density, green spaces, and facilities/amenities are associated with participation in leisure-time physical activity (PA), organized activities, and social activities with friends and peers in Norwegian 8-year-olds.	Cross-sectional	n = 23043, 8 years; Mother	Population density was operationalized as the total number of residents per square kilometres around the residential home address. There are 4 categories: ≤200 residents (reference), 201–799 (low), 800–1649 (moderate) and ≥1650 (high).	Questionnaires from the Norwegian Mother and Child Cohort Study (MoBa) to assess leisure-time physical activity; participation in organized activities; informal social activity with friends and peers	Higher population density was associated with higher odds of participation in organized and informal social activities for 8-year-olds in both sexes. Moreover, population density was negatively associated with leisure-time physical activity among 8-year-old girls.
	Sato et al. (2018)	Japan; Municipalities	Examined the relationship between population density and physical activity of youth using pedometer-determined step data.	Cross-sectional	n = 13688, 6–15 years; Child	Population density was calculated by dividing the number of residents by the habitable land area of the municipality. There are 5 categories: <2500 (lowest), 2500–5000 (lower), 5000–7500 (middle), 7500–10,000 (higher), and >10,000 people/km2 (highest).	Daily step count, followed the Tokyo Metropolitan Board of Education protocol	The lowest (<2500 people/km2) and highest (>10,000 people/km2) population density has considerably lower daily total and out-of-school step count for children compared to the reference population (5000–7500 people/km2). However, there is no significant difference in children's in-school step

(*continued on next page*)

Table 2 (*continued*)

Health Domain:	Lead author (year)	Country of origin; ecological level of study	Aim	Study design	Participant number/Age; Primary respondent	Measurement of urban density	Measurement of health or wellbeing outcome	Key findings
								count based on population density.
	Machado-Rodrigues et al. (2014) [a]	Portugal; Urban and rural	Compared physical activity, physical inactivity, time spent in screen related sedentary activities and cardiorespiratory fitness in rural and urban adolescents.	Cross-sectional	n = 362, 13–16 years; Trained staff	Urban areas were defined as a city with >500 inhabitants/km2 or >50,000 inhabitants. Rural areas were defined as villages with≤100 inhabitants/km 2 or with the total population <2000 people.	The ActiGraph GT1M accelerometer (ActiGraphTM, LLC, Fort Walton Beach, FL, USA) was used for direct assessment of physical activity and sedentary behaviour	Urban boys and girls spent less time in sedentary activities than their rural counterparts. Rural boys and girls had higher levels of cardiorespiratory fitness than their peers in urban areas. Boys in rural areas were less active in moderate-to-vigorous physical activity (MVPA) than boys in urban areas, particularly on weekends. Unlike boys, urban adolescent girls spent significantly less time in MVPA than adolescent girls in rural areas.
Other	Smalley et al. (2023)	Senegal; Urban and rural	Identified factors associated with DTP3 coverage in Senegal at both the household and regional level.	Time series data	n not reported 12–23 months; Mother	Area categories: urban and rural	Diphtheria-tetanuspertussis vaccine (DTP3) Coverage: Data extracted from Senegal's Demographic and Health Surveys	Population density was not significantly correlated with the DTP3 coverage for children. Living in urban areas is significantly associated with higher DTP3 coverage for children.
	Wardani and Wahono (2020)	Indonesia; City	Studied spatial analysis of childhood tuberculosis and social determinants in Bandar Lampung, Indonesia.	Cross-sectional	n = 73 Age not reported; Clinician	Population density is the total population of the sub-district divided by its area in kilometres square. There are 3 categories: low density (<2500 persons/km2), middle density (2501–7500 persons/km2) and high density (>7501 persons/km2).	Tuberculosis: Registered cases at Community Health Centre	Childhood tuberculosis cases mainly concentrated in highly populated areas with a population density higher than 7501 persons/km2.
	Van de Poel et al. (2007) [a]	47 developing countries: Sub-Saharan Africa, Near East, South & Southeast Asia, Latin America & Caribbean; Urban and rural	Present the magnitude and explanation of rural–urban disparities in child health throughout the developing world.	Cross-sectional	n not reported 0–5 years; Respondent not reported	Area categories: urban and rural	Under-5 mortality refers to child death before or at 60 months	On average, children in rural areas had 1.4 times higher risk of low growth and under-5 mortality. Despite the same median relative risk, urban-rural disparities in growth-stunting and under-5 mortality are not strongly correlated across countries and regions.

Notes.
[a] Health or wellbeing outcomes span multiple domains.

Gouin et al., 2015; Lauritsen et al., 2005). These numbers correspond with the range of India's least urbanised areas, from 5000 to 100,000 inhabitants (Sharma et al., 2023). The stratification methods were slightly different among the two studies that used 'address density', both of which were conducted in the Netherlands. While Evans et al. (2020) classified urbanicity on a scale from 0 to 4, considering over 2500 addresses/km^2 as very urban, Adriaanse et al. (2014) adopted a three category approach, defining urban areas as those with more than 1500 addresses/km^2. Table 2 provides a detailed overview of each study included in the review.

3.4. Synthesis of studies included

Across the 53 studies reviewed, findings on health and wellbeing outcomes relative to urban density yield mixed evidence for various indicators of urban density. Our analysis focused on six indicators – (i) child growth and nutritional status; (ii) physical health; (iii) mental health and wellbeing, (iv) child development, (v) lifestyle behaviour, and (vi) other health outcomes. Most studies showed mixed or inconclusive results for physical health and mental health and wellbeing. Urban density had a positive relationship with child growth and nutritional status in many studies conducted in Africa and Asia (n = 9 studies); but was negatively linked with child behavioural development in Asia, Europe and North and Central America (n = 8).

In all studies identified, density measures were determined by the study authors and there were no studies where children were asked about their perceptions of density. Regarding health outcomes, health staff were most frequently the primary research informants (n = 17; 32%), followed by parents/caregivers (n = 14; 26%), teachers (n = 7, 13%), or clinicians (n = 5, 9%). Health staff mostly reported on studies of growth and nutritional status, and physical fitness, while child development was mainly reported by parents or teachers. Clinicians reported clinical issues such as autism, myopia, and tuberculosis. Children self-reported outcomes in 12 studies (23%). In these studies with child respondents, the outcomes of interest were mental health and wellbeing, development, and lifestyle behaviour. The respondent type (e.g., child, clinician) was not reported in seven studies (13%); while, this does not impact the integrity of the source, it does highlight an important omission in reporting. Whether children were residing with their parents was not noted in any of the studies, thus we assumed that in all cases, urban density measures referred to the environment the child resided in.

3.4.1. Differences in links between health and density by density measure used

There was significant heterogeneity in how density was measured, limiting the ability to clearly discern differences by measurement approach. Overall, there were three main ways density was measured: 1) measures of settlement type with no further detail, 2) studies that used indices and continuous measures of density, and 3) studies that used categories for total population or population or dwelling density. Findings are presented separately here for each of these three categories, noting also the variation in how density was measured within these categories (see Table 2). Fig. 2 provides an overview of key density concepts applied and their associations with child health outcomes.

3.4.1.1. Density defined by settlement type. Across the collection of scholarship, nineteen studies (36%) compared child health outcomes between different types of settlements (i.e., urban-rural, urban slum-general urban, and village-city-town categories). The findings suggested a mixed result between urban residence and various aspects of children's health. Seven studies reported negative health outcomes in

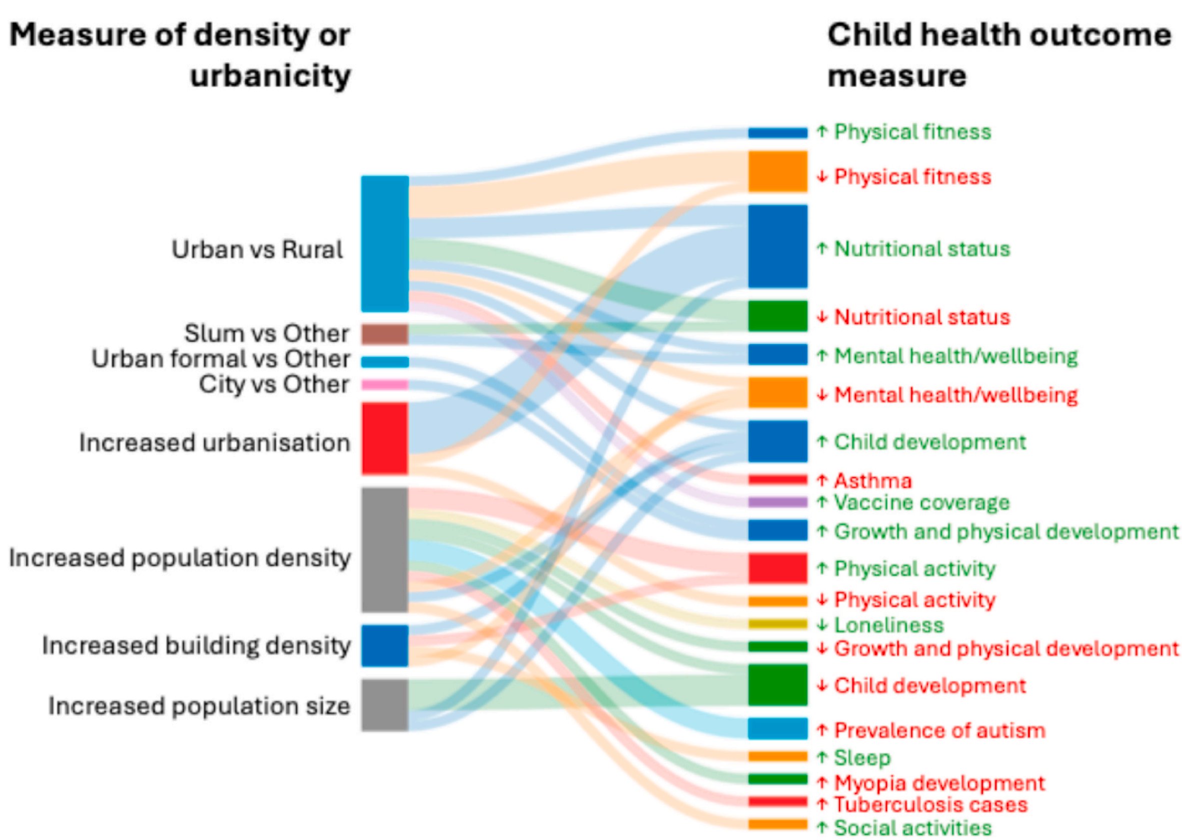

Fig. 2. Associations between measures of urbanisation or density with child health outcomes. Note: Results not shown where null or u-shaped (e.g., significant associations for both high and low density) findings were reported. Findings for continuous (indicators and indices) and categorical measures are combined for clarity.

urban children in relation to urban density. This included lower physical fitness (Tian et al., 2021; Tinazci & Emiroğ;lu, 2010; Yoshizawa, 1972), poorer nutritional status (Clark, 1980; Shah et al., 2020), higher depression levels (Bui et al., 2018), and increased prevalence of asthma (Silburn et al., 2007). However, five studies reported positive outcomes associated with urban living; including better physical fitness (Lo et al., 2017), improved nutritional status (Marais et al., 2022; Van de Poel et al., 2007), lower rates of psychiatric disorders (Chen et al., 2021; Gau et al., 2005), and higher vaccine coverage (Smalley et al., 2023). Four studies reported either no significant differences between urban and rural children (Castillo et al., 2016), or unclear results due to variations in children's performance across different tests and countries (Al-Ansari and Bella, 1998; Rutenfranz et al., 1982; Ujević et al., 2013). Regarding the remaining three categories, Izutsu et al. (2006) reported that adolescents living in slums had significantly lower nutritional status and quality of life compared to those not living in slums. However, most of the mental health indexes were higher in those residing in slums. Marais et al. (2022) demonstrated that children living in urban formal areas were significantly less likely to be stunted than those from informal urban and rural areas, and little difference was found between urban informal and rural areas. A study of boys found higher measures of physical development in cities compared to villages and country areas (Wojnicz et al., 1991).

3.4.1.2. Density defined by indicators and indices. Seventeen studies (32%) reported on urban density measurements in one or more of the four health domains. Urbanisation was consistently associated with better nutritional status (Argaw et al., 2019; Paciorek et al., 2013; Ru et al., 2022; Terra De Souza et al., 1999; Y. Zhang et al., 2019). However, evidence was found between urbanisation and increasing abdominal adiposity (Inoue et al., 2018), lower physical fitness (Dong et al., 2019), and a higher level of sedentary behaviour (Squillacioti et al., 2023). Population density was linked to decreased loneliness (Marquez et al., 2023) and an increase in children's independent activities (Zhou et al., 2022). On the other hand, a higher level of underweight (Balk et al., 2005), inadequate early development (Prado-Galbarro et al., 2021) and autism (Fathmawati et al., 2023) were linked with higher population density. For building density indicators, Collyer et al. (2022) found a positive association with physical development regardless of SES, while a positive association with social and emotional development was only found in high SES neighbourhoods. While Fernández-Barrés et al. (2022) found areas with high building density and lower population density were associated with more physical activity, less sedentary behaviour, more sleep, and more active transport; Torun et al. (2022) found no association between building density and children's mental health wellbeing and life satisfaction.

3.4.1.3. Density defined by categories for total population or population/dwelling density. The remaining eight studies (15%) used categories for increasing density based on total population or population/dwelling density with mixed results. High population density was linked to myopia development (Choi et al., 2017), high tuberculosis cases (Wardani and Wahono, 2020), lower well-being (Nordbø et al., 2020), and higher prevalence of autism (Lauritsen et al., 2014). However, some studies found that lower population density was associated with more behavioural problems (Choo et al., 2017), more sedentary time (Machado-Rodrigues et al., 2014), and lower odds of participation in organized and informal social activities (Nordbø et al., 2019). One study reported that living in areas of the lowest and in areas of the highest population density was associated with significantly lower daily step counts compared with living in areas with a moderate level of population density (Sato et al., 2018). Population size was used as an indicator for urban density in seven studies. Larger population size was negatively associated with child development (Gouin et al., 2015; Lauritsen et al., 2005; Zahner et al., 1993), but one study found significantly lower prevalence of emotional and behavioural problems in areas with the highest population size *and* areas with the lowest population size (Achenbach et al., 1991). Higher population size was associated with better nutritional outcomes (Sharma et al., 2023) and fewer psychiatric disorders (Dursun et al., 2020). The two studies that measured urban density by addresses/km^2 showed differing results, despite both being conducted in the Netherlands and assessing mental health problems. While Evans et al. (2020) found no association between urbanicity and mental health problems, Adriaanse et al. (2014) indicated that residing in urban neighbourhoods with more than 1500 addresses/km^2 was significantly associated with a higher risk of mental health problems.

3.4.2. Differences by geography

As emphasised, the collection of reviewed studies spanned five territories internationally. Here 23 studies were conducted in Asia, 15 in the European Union, 4 in North and South America, 4 in Africa, and 3 in Oceania. Four remaining studies covered multiple territories. The twenty-three studies (43%) conducted in Asia provide mixed evidence; with increased density having both negative and positive impacts on child health. Several studies also reported inconclusive results. Fifteen studies (26%) conducted in Europe focused for the most part on lifestyle behaviour, mental health and wellbeing, child development and physical health; with negative relationships between urban density and child development being reported. The remaining studies (n = 11; 21%) reported mixed results. In North and South America, child development was negatively associated with urban areas, higher population density, and intermediate urbanization. In Africa, there was consistent evidence that urban density indicators were positively linked with children's nutritional status. Likewise, four studies reported better nutritional status among urban children in countries across all geographical regions except Europe. In Oceania, rural children had better nutritional growth, but poorer physical health.

3.4.3. Differences by health outcomes

3.4.3.1. Child growth and nutritional status. 15 papers focused on child growth and nutritional status, with nine papers conducted in nine distinct countries, six papers covered multiple developing countries, spanning all geographical regions, excluding Europe. A consistent body of evidence revealed a positive relationship between urban density indicators and improved nutrition and growth outcomes in children. Residing in urban areas or increasing urbanisation was associated with a decrease in child growth-stunting (Argaw et al., 2019; Brink et al., 1983; Marais et al., 2022; Sharma et al., 2023; Van de Poel et al., 2007; Y. Zhang et al., 2019), a lower prevalence of inadequate weight gain (Terra De Souza et al., 1999), and higher indicators of child growth (Wojnicz et al., 1991). Ru et al. (2022) demonstrated that urbanisation is associated with reduced growth-stunting, wasting and underweight within the Sub-Saharan region. Additionally, Paciorek et al. (2013) suggested that urban children across 141 countries generally had a better nutritional status compared to children in rural areas. In contrast, urban children a higher prevalence of obesity or overweight (Shah et al., 2020), and abdominal adiposity (Inoue et al., 2018) compared to rural children. Balk et al. (2005) found that higher density was associated with increasing underweight levels in 45 countries across Asia, Africa, and Latin America. In an older study, Clark (1980) reported that children residing in urban areas had lower height and weight than those residing in rural areas. One study found adolescent residing in slums had a significant lower weight and BMI than those living outside of slums (Izutsu et al., 2006).

3.4.3.2. Physical health. Evidence regarding physical health was mixed. 11 papers focused on physical activities, with ten papers covering ten individual countries, and one conducted in several European countries. Five studies reported a negative association between children's physical fitness and urbanization or living in urban areas (Dong et al., 2019; Inoue et al., 2018; Tian et al., 2021; Tinazci & Emiroğ;lu, 2010; Yoshizawa, 1972). Moreover, Choi et al. (2017) found that high population density was associated with child refractive error. Living in more urbanised areas showed a higher prevalence of asthma and poorer oral health in children (Silburn et al., 2007). Conversely, one study found that children residing in urban areas had better physical fitness outcomes than those in rural areas (Lo et al., 2017; Wojnicz et al., 1991). A further two studies, however, presented inconclusive results, reporting inconsistencies across different fitness test components in children (Ujević et al., 2013) and among four European countries (Rutenfranz et al., 1982). Castillo et al. (2016) found no significant difference in physical activity levels between urban-dwelling and rural-dwelling children.

3.4.3.3. Mental health and wellbeing. Similarly, studies investigating children's mental health and well-being presented conflicting results. Nine papers between nine countries focused on child mental health and wellbeing, with seven concentrating on mental health and two concerned with wellbeing. Two studies identified a positive association, indicating that urban density was linked to a lower level of loneliness (Marquez et al., 2023) and a reduced risk of developing depressive traits in children (Chen et al., 2021). Five studies reported conflicting results: urban density was associated with lower subjective well-being (Nordbø et al., 2020), higher risk of mental health conditions (Adriaanse et al., 2014; Silburn et al., 2007), higher prevalence of stress (Shah et al., 2020), and higher level of depression in children (Bui et al., 2018). One study found no association between building density and child mental health and well-being (Evans et al., 2020; Torun et al., 2022). Another study reported adolescents residing in slum areas had better mental health indices but poorer quality of life compared to their peers residing outside of slum areas (Izutsu et al., 2006).

3.4.3.4. Child development. 14 papers between 12 countries focused on child development and findings were multifaceted. Several studies showed a positive relationship between urban density indicators and child development. These included reduced behavioural problems in vulnerable children (Choo et al., 2017), improved physical, social and emotional development in high SES neighbourhoods (Collyer et al., 2022), and lower prevalence of psychiatric disorders (Dursun et al., 2020; Gau et al., 2005). Conversely, other studies identified potential risks associated with urban density: a higher risk of autism (Fathmawati et al., 2023; Lauritsen et al., 2005, 2014), higher rates of emotional and behavioural problems (Zahner et al., 1993), lower cognitive neurodevelopment (Gouin et al., 2015), delayed social and emotional development in low SES neighbourhoods (Collyer et al., 2022), and poor early childhood development (Prado-Galbarro et al., 2021). Despite these findings, the impact of urban density remained unclear in three studies: Achenbach et al. (1991) found a weak association between urbanisation and behavioural and emotional problems; Weiss et al. (2020) reported an inconclusive result, with urbanisation showing a negative association with child psychopathology in cross-sectional analysis but no significant impact on child functioning in longitudinal analyses; and Al-Ansari and Bella (1998) highlighted that both urban and rural settings positively impacted certain aspects of child development. One study found no association between urbanicity and behavioural and emotional issues in children (Evans et al., 2020).

3.4.3.5. Lifestyle behaviour. Eight papers focused on lifestyle behaviour. Of these, seven were conducted in six different countries, and one spanned across six European countries. Evidence for associations between urban density and unhealthy lifestyle behaviours was found. Urban children ate less healthily when experiencing stress (Shah et al., 2020), had a significant lower weekly out-of-school physical activity (Tian et al., 2021), and higher level of sedentary behaviour (Squillacioti et al., 2023) compared to children in rural areas. Similarly, high population density was associated with less physical activity (Nordbø et al., 2019; Fernández-Barrés et al., 2022), more sedentary behaviour, less sleep and less active transport (Fernández-Barrés et al. (2022). However, higher population density was associated with higher odds of participation in organized and informal social activities (Nordbø et al., 2019), and independent activities (Zhou et al., 2022). Machado-Rodrigues et al. (2014) also found that urban boys and girls spent less time in sedentary activities compared to their rural counterparts. Additionally, urban boys were more active in physical activity compared to rural boys, which contrasts with the trend observed in girls. Sato et al. (2018) showed that both the lowest and highest population densities were linked to lower physical activity.

3.4.3.6. Other health outcomes. Three remaining papers focused on under-5 mortality across 47 developing countries, DTP3 vaccine coverage in Senegal, and tuberculosis cases in Indonesia. Children in rural areas had higher under-5 mortality (Van de Poel et al., 2007), lower level of DTP3 vaccine coverage (Smalley et al., 2023). Wardani and Wahono (2020) found that childhood tuberculosis was mainly concentrated in highly populated areas.

4. Discussion

4.1. Key findings

Our scoping review of urban density and child health and wellbeing, revealed a geographically widespread and interdisciplinary field that is rapidly expanding. We provide the first 'map' of how urban density has been measured internationally, and how this has been linked with child health. In doing so, we present two novel challenges for future research, policy and practice exploring density and child health: firstly the need to consider contextual complexity when undertaking research and urban design practice, or developing associated policy; and secondly the need for improved reporting and clarity in how urban density is defined. The findings from this review can help inform future research including study design, measurement of density, contextualising findings in the international evidence base, and improving reporting of methods.

(i) Contextual complexity of urban density for children's health

Reflecting our permissive inclusion criteria, we found considerable heterogeneity in the literature, across both density and health measures. Our findings showed variation in environmental definitions and measures, and reporting of these, both between and within countries, similar to previous studies (Black et al., 2024; M. Kyttä, 2002; M Kyttä et al., 2018). Differences between countries were expected, with variations in economic development, geographical features, culture, and policy and planning influencing what density looks like relative to a country. However, we also identified within-country differences in density measurement, indicating that this is possibly more nuanced and locally relevant. Our search strategy yielded research across a wide array of child health outcomes, encompassing communicable and non-communicable diseases, health behaviours, health risk, and physical and mental health outcomes. Among these, we found consistent evidence of positive associations between urban density and improved growth and nutritional status in Asia and Africa, while negative impacts on child development were reported in studies from Europe and North America. The contextual differences in urban density likely contribute to the regional variety in child health outcomes observed from this study. In developing countries like Asia and Africa, urban density is often characterized by rapid economic growth, which is accompanied with better socioeconomic status, higher maternal education, improved access to sanitation infrastructure and healthcare facilities (Behrens et al., 2014; Bhui et al., 2023; Garrett and Ruel, 1999; Hirvonen et al., 2017;

Rutherford et et., 2010). These factors can lead to improved nutritional status in children. In Europe and North America, negative impact of urban density on child development is likely attributed to social stressors, especially low social cohesion and crime victimization (Allardyce et al., 2005; Newbury et al., 2016), which are found in urban areas of developed countries.

Overall, the research reflected the complexity of considering density as an all-encompassing concept, and reflected a mixed and multifaceted relationship between urban density and child health and well-being. There was consistent evidence of a positive association between urban density and children's better nutritional status in Asia and Africa, while a negative impact on child development was observed in Europe and North America. The relationship between urban density and children's mental and physical health yielded mixed or inconclusive findings. This review highlights both the positive and negative impacts of urban density on children's health and wellbeing across different geographic locations and density measurements. It provides nuanced evidence about the impact of density, compared to the dominant perception that urban density is harmful. However, what it does not capture is children's freedom to play relative to the density of their immediate environment, a nuanced understanding of children's independent mobility and spatial affordances relative to density, or detail on participatory approaches which gather children's perspectives of density (e.g., see Lester and Russell (2010) and Martin et al. (2023)).

(ii) Improved reporting and clear use of terminology and indicators for urban density

Heterogeneity in findings was anticipated given our a-priori broad approach to identifying literature, and findings from previous reviews (Audrey and Batista-Ferrer, 2015; Martin et al., 2023; Pitt et al., 2021). We also anticipated geographical nuance in conceptualisation of key indicators; however this was challenging to assess due to lack of reporting. Specifically, measurement largely focused on urbanicity versus rurality (or other measures), which was not further defined. We included these studies in this review, considering this categorisation as implying higher versus lower degrees of density. However, it is important to note these categories alone are limited indicators of density. This highlights an urgent need for improved reporting of how key environmental measures are being defined and calculated. Consistent approaches are needed to enable comparability and to develop a comprehensive understanding of where and how urban density impacts child health. Furthermore, associations may not be linear, making arbitrary thresholds for defining area-level indicators, and relative levels of high/low density limited. More nuanced and context-specific approaches are needed, for example it is likely u-shaped relationships may exist in areas with relatively higher levels of urban density and that these relationships may also differ by the spatial scale being used. Careful consideration of which indicators and indices are most appropriate and best suited to the research question and local context is necessary in future research, including developing a clear rationale and method for any given measure (e.g., Pineo et al. (2018) provide a useful systematic review of Urban Health Indicator Tools of the Physical Environment).

Notwithstanding the obvious differences due to variation in health outcomes of interest, there remains a clear need to improve reporting mechanisms for research in this field. An array of reporting standards exists. Of most relevance to this research are the STrengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement for cohort studies (von Elm et al., 2008), and the Spatial Lifecourse Epidemiology Reporting Standards (ISLE-ReST) statement (Jia et al., 2020). Here, we provide an adjunct to these statements for studies interested in urban density and child health (Table 3).

Table 3
Recommended reporting measures for studies investigating urban density and health.

Measure	Description/recommendation
Population or dwelling density	Provide measure of population/dwelling density used to characterise degrees of urbanisation. Detail source of data and date collected. If thresholds are used, provide rationale for their calculation and categories used.
Urban/rural or urbanicity	Detail how urban and rural categories (or urbanicity) were determined, ideally using measures of population or dwelling density, and any other available indicators to enable comparability.
Area categories (town, village, etc.)	Provide detailed characteristics to enable comparison across geographic regions (e.g., population or dwelling density, natural boundaries, definitions, etc.).
General	Present an overview of the social and cultural context of the research, including any relevant historical developments. Provide detail on the context of the research in terms of population density for the region of study. Provide information on relevant indicators to allow global comparisons (e.g., OECD Better Life Index, Social Progress Index). Outline the theoretical positioning for the hypothesised relationship – including any measured/unmeasured and direct/indirect pathways between urban density and health. Consider/report on use of relevant frameworks, e.g., the Towards Healthy uRbanism: InclusiVe Equitable Sustainable (THRIVES) framework (Pineo, 2022). Report on the informants to the research (e.g., children, parents, teachers, health professionals, datasets etc).
Indices	Provide detail on how all contributing indicators have been measured/calculated, and their relative contribution to the index.

4.2. Strengths and limitations

This review took a systematic approach to identifying literature that examined links between measures of urban density and child health. Our comprehensive approach to conceptualising density provided a wide scope of relevant literature: capturing a diverse array of conceptualisations of density, providing evidence spanning all continents, and highlighting the need for clear definitions and consistent terminology. While we used a thorough approach for density search terms, we used broader search terms for both the population group (e.g., we did not extend search terms to specific population groups such as infants or toddlers) and health outcomes (i.e., we used general search terms to capture health outcomes, but did not include specific search terms for the gamut of possible health outcomes). Our focus was pragmatic in terms of seeking to provide a contemporary and global understanding of how density has been measured in relation to child health. However, our review was not designed to capture theoretical or critical perspectives on urbanisation and health (see for example Verheij (2006) or considering geographical drift and breeder hypotheses in understanding urban-rural health differences). Although we did not undertake a formal quality assessment, in keeping with the purpose and role of a scoping review and recognising the extremely heterogeneous body of literature, this review presents some important prompts for improving quality in reporting on future research.

Caution must be applied when considering the results of this review, particularly regarding findings from cross-sectional studies. Most of the studies included in the review were cross-sectional, limiting our ability to understand causal links between urban density and child health. It is possible, for example, that the increased prevalence of health problems we observed in more dense/urbanised settings was due to families choosing to reside in these areas to have better access to necessary healthcare services. Considerably more research is needed that enables us to understand causality in these relationships. Moreover, this review focused on area-level measures of urban density, and did not consider individual-level exposures or use of differing settings. Future reviews that explore urban density features at the individual level and their relationships with child health outcomes will be important additions to the research field. Our search strategy was limited to English language articles, thus the findings here only reflect this scholarship. In the interest of attaining a broad understanding of the evidence base we did not set any time limits; however, this may have hindered an up-to-date understanding of urban density and health.

4.3. Future directions

As well as new longitudinal research, opportunistic use of other methods would be worthwhile; for example drawing from existing health panel surveys and measurement of changes due to relocation data (such as in the RESIDential Environment (RESIDE) study (Hooper et al., 2020)). It is also worth noting that inequity exists in how people experience urbanised environments. While urban-dwelling poor face significant barriers to health, less disadvantaged urbanites are able to reap the rewards of increased access and availability of services (Elsey et al., 2019). Ultimately, researchers interested in links between urban density and children's health must consider broader social determinants of health (Schulz and Northridge, 2004), and seek to understand issues of environmental justice (Cutts et al., 2009; Y Zhang et al., 2024). Approaches that acknowledge these broader impacts on health, such as the THRIVES framework (Pineo, 2022), may be useful in future research. Use of such approaches could also help unpack and explain some of the heterogeneity observed in the current evidence base.

A detailed examination of the multiple pathways from urbanisation to children's health outcomes was beyond the scope of this review, and the literature identified did not allow for such an examination. For example, the impacts of noise pollution likely impact distress and child behaviour/development as well as physical health outcomes (Bhui et al., 2023; Stansfeld et al., 2000). Similarly, air pollution is a known driver of respiratory illness for children residing in urban areas (Altman et al., 2023). However, only one study (Weiss et al., 2020) specifically measured noise and air pollution and these measures were combined with others into an overall indicator of urbanisation - hindering our ability to understand the relative contributions of these factors to health outcomes. Given the myriad health outcomes identified in the review, it is likely that separate examinations for different health outcomes that provide a detailed exploration of associations and mechanisms for links between density and health are warranted.

Children's views on density were not captured in the studies identified in this review. To some extent this may have been due to our search strategy and terms, which did not actively seek to identify children's perceptions; additionally, it is likely that children's perceptions are not commonly sought on this topic. This is an important knowledge gap that warrants attention in future empirical research and literature reviews. Children have the right to have their views on matters of importance to them heard and respected. Participatory research approaches on urban density, with children involved as rightful decision-makers with expertise to voice their experiences of space/place can shed light on children's specific experiences of urban density (Sullivan et al., 2020; T Williams et al., 2024). Considerations of children as active collaborators and capable experts rather than passive objects is necessary. To activate children's voice, child-friendly and flexible data collection approaches that are place-based and context-specific are important (M Smith, Spencer, Fouché and Hoare, 2021). In this context, mixed-methods and multiple-methods studies including approaches such as participatory geographic information systems (PPGIS); digital games/models, workshops/charrettes, and flexible creative methods can be powerful facilitators for generating insights about children's preferences, perceptions, and experiences of built settings in different contexts (see, for example, Bishop and Corkery (2017); Martin et al. (2023); T. Williams et al. (2022); Egli et al. (2019)).

5. Conclusion

The synthesis of evidence from this scoping review brought together an improved awareness of critical issues in understanding the relationship between urban density and child health and wellbeing for future research, policy and practice. Ultimately, this review has identified a need for further research in this field, that recognises the multiple (and sometimes competing) characteristics of urbanicity that can contribute to different child health outcomes in different ways – considering the direct and indirect pathways between individual characteristics, and their relative contributions to a range of child health measures, from the perspectives of different respondents. Recognition of geographic nuance is essential – highlighting the importance of clear and consistent terminology for describing and measuring physical geographic characteristics, as well as the need to consider the social and cultural context of the research. We invite researchers, policy makers and practitioners to engage with the complexity of urban density and explore interdisciplinary and interprofessional avenues to bolster and promote nuanced accounts of urban density for children's health to explore opportunities for comprehensive and consistent approaches to urbanicity and child health measures.

CRediT authorship contribution statement

Luy Dau: Writing – review & editing, Writing – original draft, Investigation, Formal analysis, Data curation. **Paula Barros:** Writing – review & editing, Methodology, Funding acquisition, Conceptualization. **Elizelle Juanee Cilliers:** Writing – review & editing, Methodology, Funding acquisition, Conceptualization. **Bronwyn Hemsley:** Writing – review & editing. **Michael Martin:** Writing – review & editing. **Monica Lakhanpaul:** Writing – review & editing. **Melody Smith:** Writing – original draft, Supervision, Project administration, Methodology, Funding acquisition, Formal analysis, Data curation, Conceptualization.

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